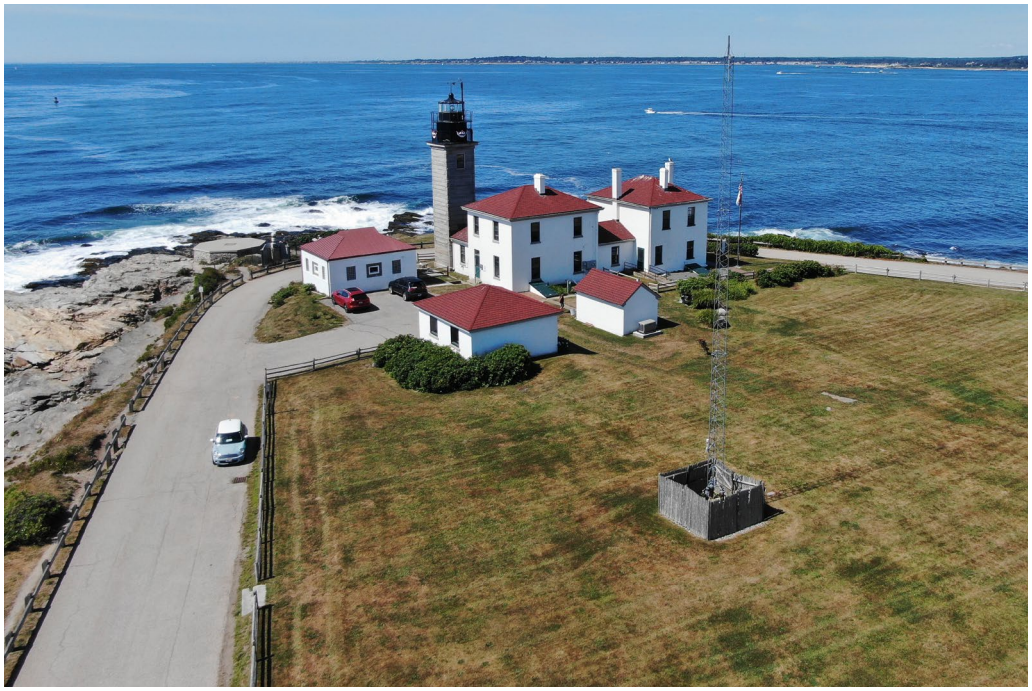
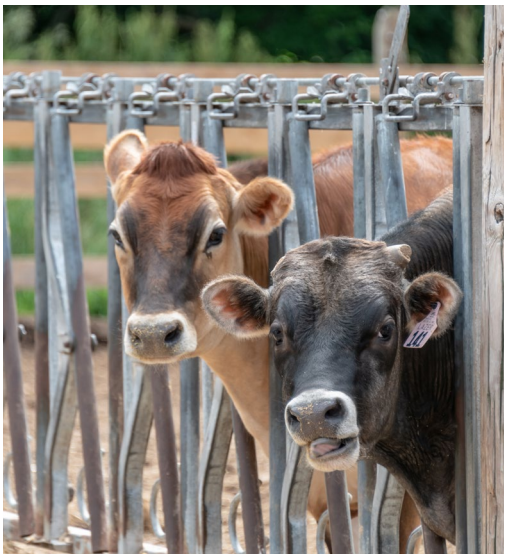


DEM
RHODE ISLAND

DECEMBER 2024



2022 RHODE ISLAND
GREENHOUSE GAS INVENTORY

AN ASSESSMENT OF RHODE ISLAND'S PROGRESS TOWARDS THE ACT ON CLIMATE

RIDEM Photo

Salty Brine State Beach in Narragansett

Introduction

The *2022 Rhode Island Greenhouse Gas Inventory* is produced by the Rhode Island Department of Environmental Management (DEM) to assess the annual climate-warming emissions produced in Rhode Island. This evaluation is the primary scientific tool used by the Rhode Island Executive Climate Change Coordinating Council (EC4) to assess progress towards the economy-wide greenhouse gas (GHG) emissions reduction mandates required by the Act on Climate.[1] The inventory is an estimate of emissions sources and sinks and is recalculated each year based on the best science and data available. Methodologies evolve year-to-year, and emissions estimates from previous inventories should not be used as a direct comparison since adjustments have been made. Refer to the Technical Appendix for a full explanation on applicable adjustments to the 1990 baseline and subsequent year's data.

KEY FINDINGS

- Rhode Island emitted 9.60 million metric tons of carbon dioxide equivalent ($MMTCO_2e$) in 2022.
- The state's emissions decreased by 2.2% from 2021 levels.
- Emissions decreased by 18.3% since 1990, but were 32.6% above the Act on Climate's 2030 mandate.

Short-Term Trends

TRANSPORTATION

Most of Rhode Island's emissions, 36.6%, continued to stem from the transportation sector (3.78 $MMTCO_2e$) in 2022. The over 918,000 passenger cars, trucks, and motorcycles registered in the state produced 64.9% of transportation emissions and were responsible for 20.6% of overall emissions. Medium-and-heavy-duty vehicles, including buses, refuse trucks, motor homes, and tractor trailers, comprised 20.6% of the transportation sector. Construction and utility equipment (6.6%), aircraft (6.1%), watercraft (1.7%), and rail (0.01%) contributed the remainder of transportation sector emissions. Since 2021, emissions from transportation decreased 3.4%. A drop in highway vehicle emissions (-0.13 $MMTCO_2e$) drove most of the annual change in the transportation sector's emissions. Highway vehicle emissions are strongly correlated with vehicle miles traveled (VMT), and a small shift in VMT can greatly alter emissions. Between 2021 and 2022, statewide VMT decreased 0.05% according to data provided by the Rhode Island Division of Statewide Planning. Conversely, aircraft emissions rose 18.6% alongside a 36% jump in passenger travel at Rhode Island T.F. Green International Airport.[2]

Highway vehicle emissions continue to be estimated with a customized version of the U.S. Environmental Protection Agency's (EPA) Motor Vehicle Emissions Simulator (MOVES) that includes state-specific VMT data from the Rhode Island Division of Statewide Planning and vehicle registration data from the Rhode Island Division of Motor Vehicles. Aircraft emissions estimates were provided by the Rhode Island Airport Corporation (RIAC), as has been the case since 2010. DEM was notified on March 18, 2024, that RIAC will no longer provide this critical dataset required under The Permanent Air Quality Monitoring Act.[3] A similar dataset has yet to be identified. Distillate and residual fuel consumption data collected by the U.S. Department of Energy and gasoline consumption data collected by the U.S. Department of Transportation were used to estimate emissions from construction and utility equipment, watercraft, and rail.[4,5]

RESIDENTIAL, COMMERCIAL, AND INDUSTRIAL BUILDINGS

Emissions from residential, commercial, and industrial buildings result from the combustion of natural gas, oil, and propane for space heating, water heating, air conditioning, and cooking. Industrial building emissions also include fuel used for district heating systems or manufacturing. In 2022, residential buildings comprised 20.5% (2.12 $MMTCO_2e$) of total statewide emissions. Commercial buildings, such as hospitals and universities, produced 9% (0.93 $MMTCO_2e$) of total emissions. Facilities that produce, process, or assemble goods are classified as industrial buildings and contributed 5.7% (0.59 $MMTCO_2e$) of total emissions in 2022. Emissions from wood burning stoves are also included in the residential and commercial buildings sectors.[6]

3.64 $MMTCO_2e$ in 2022 ***combined emissions from residential, commercial, and industrial buildings***

Residential building emissions are correlated with winter weather through heating degree days (HDDs).[7] In 2022, Rhode Island accumulated 5.2% more HDDs than in 2021.[8] Despite the slightly cooler year, residential building emissions dropped by 1.2% due to small changes

in petroleum and natural gas consumption. It is plausible 2022's decrease in residential building emissions is related to advances in energy efficiency, building weatherization, and the electrification of heating equipment. More than 920 heat pumps fully or partially displaced delivered fuel oil between 2021 and 2022, according to the Rhode Island Office of Energy Resources.[9] Emissions from residential buildings that heat with wood increased by 25% in alignment with the cooler year. Residential, commercial, and industrial building emissions continue to be estimated with fuel consumption data collected by the U.S. Department of Energy.[4]

OFFICE OF ENERGY RESOURCES PHOTO

A modern heat pump in operation — an energy-efficient system that indirectly produces emissions through electricity consumption and potential leaks of hydrofluorocarbons (HFCs), a potent greenhouse gas.

ELECTRICITY CONSUMPTION

In 2022, electricity consumption was Rhode Island's third largest emissions source and contributed 18.6% (1.92 $MMTCO_2e$) of the statewide total. Electricity consumption emissions originate from power plants connected to the regional electric grid that serves Rhode Island customers. Since electricity flows freely across state lines, this sector includes emissions imported from outside of Rhode Island.[10] Between 2021 and 2022, emissions from electricity consumption slightly decreased by 1.2%. State law partially governs emissions from this sector; Rhode Island offset 19.3% of its total electricity use with renewable sources in 2022.[11] This includes the 19% required by the Renewable Energy Standard (RES) in 2022 and an additional 0.3% from voluntary clean energy programs.[12]

The wholesale energy market, facilitated by grid operator ISO New England, also influences emissions from electricity consumption. Nuclear and natural gas power plants are typically the least-cost electric generators and are frequently dispatched to meet electric demand. During periods of extreme cold, gas utilities have priority over New England's limited supply of natural gas. ISO New England must dispatch oil power plants instead. Frequent cold weather and expensive imported liquified natural gas (LNG) due to the war between Russia and Ukraine increased the price of natural gas above $20/MMBtu in 2022 for the first time since 2014.[13] As a result, New England's oil-fired power plants produced 4.5 times more electricity in January 2022 than in all of 2021.[13] This is one possibility why the carbon intensity of New England's electricity supply increased by 5.2% in 2022, which prevented a larger drop in Rhode Island's electricity consumption emissions. The RES will continue to decrease electricity consumption emissions over a longer timescale. Since offshore wind is a cost-effective alternative to natural gas during the winter, the Revolution Wind and the SouthCoast Wind projects are key to the decarbonization of this sector. Annual fluctuations in electricity consumption emissions are expected prior to the RES reaching 100% in 2033 since the wholesale energy market will continue to supply part of Rhode Island's electricity.

OTHER SECTORS

Industrial processes and product use (IPPU) constituted 6% (0.62 $MMTCO_2e$) of total emissions in 2022 and grew 3.1% since 2021. Fugitive hydrofluorocarbons (HFCs) from refrigeration, air conditioning, and aerosols contributed 95.6% of this sector. Smaller quantities of carbon dioxide (CO_2) from urea and soda ash used for various chemical applications produced the remainder of IPPU emissions. Fugitive methane leaks from Rhode Island's gas distribution system produced 2.4% (0.25 $MMTCO_2e$) of total emissions in 2022, down 2.8%. Rhode Island Energy, formerly National Grid, replaced or abandoned 67.4 miles of leak-prone mains and 2,134 antiquated services in 2022.[14] Waste emissions (1.1% of total) stem from decaying organic matter at the Central Landfill in Johnston and the 19 wastewater treatment facilities across Rhode Island. Between 2021 and 2022, emissions from waste decreased by 0.01 $MMTCO_2e$. Agriculture emissions (0.2% of total) represent methane (CH_4) from livestock and nitrous oxide (N_2O) from fertilizer applied to soil. In 2022, agriculture emissions decreased by 0.01 $MMTCO_2e$ due to the continued decline of the state's livestock population. Carbon removed by Rhode Island's natural and working lands (NWLs) offset 7.2% of statewide emissions in 2022.

Long-Term Trends

Rhode Island's commitment to climate change mitigation and investment in renewable energy sources, along with regional and global economic trends, have substantially decreased emissions since 1990.

LARGEST SECTOR TRENDS

Transportation emissions declined
18.3%

Residential heating emissions declined
10.9%

Electricity consumption emissions declined
31.7%

In the 32 years since 1990, the transportation sector has become significantly more fuel efficient as Federal and State regulations have been tightened to reduce air pollution. Rhode Island adopted California's more stringent emissions standards for passenger cars under Section 177 of the Federal Clean Air Act in 2008. Today's iteration of this regulation, colloquially known as "Advanced Clean Cars II", will continue to reduce transportation sector emissions in the future.[15] Electricity consumption emissions declined from New England's shift from oil and coal to lower-emitting, highly efficient natural gas electric generators. Advances in transmission capacity to carry imported electricity into New England, primarily Canadian hydropower, reduced emissions from imported electricity. The implementation of the RES in 2007 also reduced emissions from electricity consumption by encouraging the growth of renewable energy. The transition from delivered fuel oil to natural gas, advances in energy efficiency, and improvements in weatherization has slowly declined in residential and commercial building emissions. Since 1990, the Rhode Island Resource Recovery Corporation's advances in landfill gas collection technology at the Central Landfill have significantly reduced methane emissions from solid waste disposal by 97.3%.

The end of steel manufacturing (1994) and semiconductor manufacturing (2000) in Rhode Island eliminated GHG emissions from the metal and electronics industries. However, the replacement of ozone-depleting substances with high global warming potential HFCs across the United States have magnified total IPPU emissions by 555% since 1990. CH_4 and N_2O emissions from wastewater treatment and discharge increased by 9.2% as the state's population grew over the last three decades. The ongoing development of forest land continues to reduce the amount of CO_2 the state can naturally remove from the atmosphere. In 2022, forest lands removed 6% less CO_2 from the atmosphere compared to 1990. Rhode Island's landscape stores more carbon today (an additional -0.14 $MMTCO_2e$) because forests have matured in the absence of large fires and timber harvests. Significant amounts of dead wood from the spongey moth outbreak of 2015-2018 also remain in the ecosystem and continue to store carbon. NWLs offset a greater percentage of Rhode Island's gross emissions in 2022 than in 1990 despite ~30,000 fewer forested acres. However, this is potentially a short-lived trend and may reverse in the next few decades if forest land continues to be developed.

RIDEM Photo

Blackstone Valley River Bikepath

Conclusion

Rhode Island's economy-wide emissions fell by 2.2% between 2021 and 2022. The economic rebound from the pandemic was still evident in 2022, as emissions were higher than 2020 (+6.3%). Total emissions were slightly lower than pre-pandemic 2019 (-0.3%). While overall transportation sector emissions declined, an 18.6% increase in aviation emissions prevented a larger drop. Progress was made in the decarbonization of residential buildings, as 2022 represents only a handful of recent years where emissions decreased despite an overall cooler year. Electricity consumption emissions also declined as the RES required 19% of the state's electricity originate from emissions-free renewable sources. Economy-wide emissions in 2022 were 18.3% (2.15 $MMTCO_2e$) below 1990 levels. However, emissions were 32.6% (3.14 $MMTCO_2e$) above the Act on Climate's requirement of *45% below 1990 levels by 2030*. Rhode Island's emissions must decline an additional 26.7% over the following 8 years. Significant decarbonization of transportation, electricity consumption, and buildings are instrumental to attain net-zero emissions by mid-century.

The attached Technical Appendix details methodology updates implemented since the last inventory was released in June 2024. DEM is committed to scientifically evaluating Rhode Island's path towards net-zero emissions and will tentatively publish the *2023 Rhode Island Greenhouse Gas Inventory* no later than December 2025. For more information, visit dem.ri.gov/ghg-inventory. Learn more about Rhode Island's climate change mitigation and resilience efforts at climatechange.ri.gov.

HISTORICAL GREENHOUSE GAS EMISSIONS BY SECTOR

All Units in Million Metric Tons Carbon Dioxide Equivalent ($MMTCO_2e$)

	1990	2010	2019	2020	2021	2022
Energy	**11.93**	**11.49**	**9.62**	**9.05**	**9.80**	**9.60**
Transportation	*4.63*	*4.77*	*4.22*	*3.74*	*3.92*	*3.78*
Aviation	0.33	0.26	0.28	0.06	0.20	0.23
Highway Vehicles	3.98	4.06	3.60	3.34	3.37	3.24
Non-Road Sources	0.33	0.44	0.34	0.34	0.35	0.32
Electricity Consumption	*2.82*	*2.64*	*1.48*	*1.73*	*1.95*	*1.92*
Residential Buildings	*2.38*	*2.25*	*2.09*	*1.91*	*2.15*	*2.12*
Commercial Buildings	*1.13*	*0.92*	*0.94*	*0.80*	*0.94*	*0.93*
Industrial Buildings	*0.65*	*0.60*	*0.62*	*0.60*	*0.59*	*0.59*
Natural Gas Distribution	*0.33*	*0.31*	*0.27*	*0.26*	*0.26*	*0.25*
Industrial Processes and Product Use	**0.10**	**0.41**	**0.51**	**0.58**	**0.60**	**0.62**
Agriculture	**0.06**	**0.04**	**0.03**	**0.03**	**0.03**	**0.02**
Waste	**0.28**	**0.35**	**0.23**	**0.12**	**0.12**	**0.11**
Solid Waste Disposal	*0.18*	*0.25*	*0.13*	*0.02*	*0.02*	*0.00*
Wastewater Treatment and Discharge	*0.10*	*0.10*	*0.10*	*0.11*	*0.11*	*0.11*
TOTAL GROSS EMISSIONS	**12.37**	**12.29**	**10.39**	**9.78**	**10.55**	**10.35**
Natural and Working Lands	*-0.61*	*-0.74*	*-0.76*	*-0.75*	*-0.73*	*-0.75*
TOTAL NET EMISSIONS	**11.76**	**11.55**	**9.63**	**9.03**	**9.82**	**9.60**

** Emissions converted to $MMTCO_2e$ with the metric GWP_{100} from the Fifth Assessment Report (AR5) of the Intergovernmental Panel on Climate Change (IPCC), also available at ipcc.ch/report/ar5/syr. The complete 1990-2022 dataset is available at dem.ri.gov/ghg-inventory.*

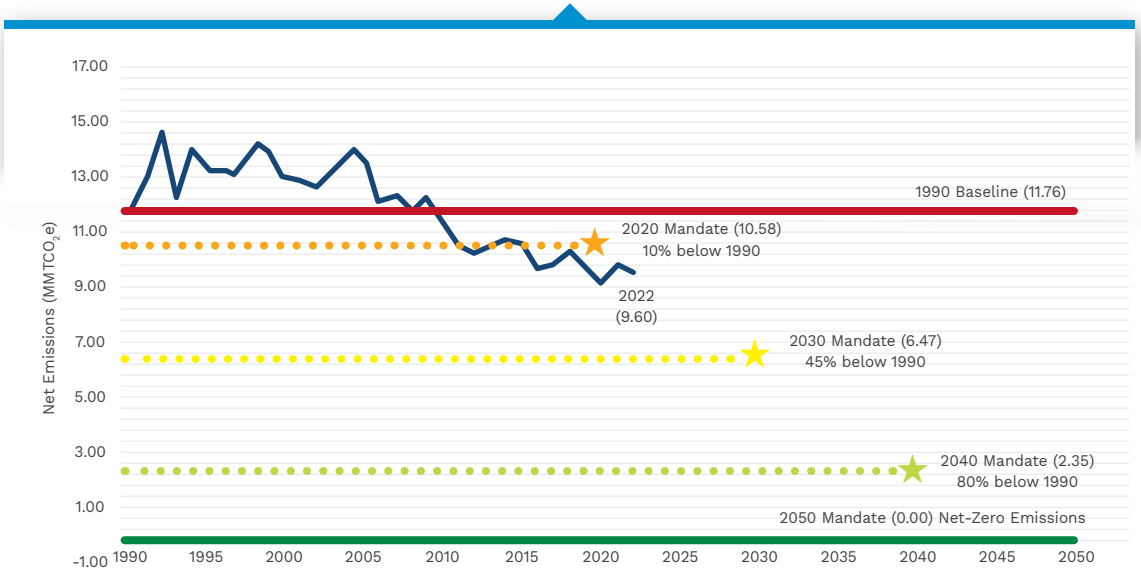
HISTORICAL GREENHOUSE GAS EMISSIONS BY GAS

All Units in Million Metric Tons Carbon Dioxide Equivalent ($MMTCO_2e$)

	1990	2010	2019	2020	2021	2022
Carbon Dioxide	**11.45**	**11.10**	**9.30**	**8.74**	**9.48**	**9.29**
Methane	**0.66**	**0.68**	**0.52**	**0.40**	**0.39**	**0.38**
Nitrous Oxide	**0.19**	**0.12**	**0.09**	**0.08**	**0.10**	**0.09**
Fluorinated Gases	**0.06**	**0.39**	**0.49**	**0.56**	**0.58**	**0.60**
Perfluorocarbons and Nitrogen Trifluoride	*0.01*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Sulfur Hexafluoride	*0.06*	*0.02*	*0.00*	*0.00*	*0.00*	*0.00*
Hydrofluorocarbons	*0.00*	*0.37*	*0.49*	*0.56*	*0.58*	*0.60*
TOTAL GROSS EMISSIONS	**12.37**	**12.29**	**10.39**	**9.78**	**10.55**	**10.35**
TOTAL NET EMISSIONS	**11.76**	**11.55**	**9.63**	**9.03**	**9.82**	**9.60**

** Emissions converted to $MMTCO_2e$ with the metric GWP_{100} from the Fifth Assessment Report (AR5) of the Intergovernmental Panel on Climate Change (IPCC), also available at ipcc.ch/report/ar5/syr. The complete 1990-2022 dataset is available at dem.ri.gov/ghg-inventory.*

1990-2022 RHODE ISLAND GREENHOUSE GAS EMISSIONS
ACT ON CLIMATE REQUIREMENTS



Technical Appendix

The Rhode Island Department of Environmental Management (DEM) strives to incorporate contemporary climate science into the *Rhode Island Greenhouse Gas Inventory* whenever possible. The *2006 IPCC Guidelines for National Greenhouse Gas Inventories* and its refinements, internationally recognized as the gold standard for greenhouse gas (GHG) inventories,[16] is the accounting framework unless endorsements are made by the Rhode Island Executive Climate Change Coordinating Council (EC4). This Technical Appendix serves to inform interested readers of methodology changes and updates since the 2021 inventory was published in June 2024. Additionally, **see page 15** for supplemental information on biogenic carbon dioxide (CO_2) emissions from electricity consumption.

ADJUSTMENTS TO HISTORICAL EMISSIONS ESTIMATES

In October 2023, DEM opened a 14-day public comment period on proposed methodology improvements to the inventory's 1990 baseline. In addition to revising the 1990 baseline for the first time in a decade, feedback was solicited about applying relevant methodology updates to the 1990 baseline and subsequent years on an as-needed basis in the future. This practice was implemented in June 2024. Since the inventory's timeseries is now recalculated each year to incorporate new emissions factors or new datasets, past iterations of the *Rhode Island Greenhouse Gas Inventory* should not be used as a direct comparison. The following table showcases numerical adjustments to years 1990 and 2021 and their comparison to 2022. It is important to note that similar adjustments have been applied to all historical estimates where applicable. The complete 1990-2022 dataset can be found at dem.ri.gov/ghg-inventory.

WHAT'S NEW?

- Improved fuel consumption data used to estimate non-road source emissions, **see page 11.**
- Improved estimates of livestock emissions, **see page 12.**
- Added estimates of emissions from agricultural soil liming, **see page 13.**
- Added estimates of emissions from flooded land, **see pages 13, 14.**
- Improved estimates of emissions flux from forest land, **see page 14.**

HIGHLIGHTED ADJUSTMENTS TO THE 1990 BASELINE AND 2021 INVENTORY

All Units in Million Metric Tons Carbon Dioxide Equivalent ($MMTCO_2e$)

	1990 (Previous)	1990 (New)	2021 (Previous)	2021 (New)	2022 (New)
Energy	**11.91**	**11.93**	**9.84**	**9.80**	**9.60**
Transportation	*4.65*	*4.63*	*3.98*	*3.92*	*3.78*
Aviation	0.33	0.33	0.20	0.20	0.23
Highway Vehicles	3.98	3.98	3.37	3.37	3.24
Non-Road Sources	0.35	0.33	0.42	0.35	0.32
Electricity Consumption	*2.82*	*2.82*	*1.95*	*1.95*	*1.92*
Residential Buildings	*2.38*	*2.38*	*2.15*	*2.15*	*2.12*
Commercial Buildings	*1.13*	*1.13*	*0.94*	*0.94*	*0.93*
Industrial Buildings	*0.61*	*0.65*	*0.56*	*0.59*	*0.59*
Natural Gas Distribution	*0.33*	*0.33*	*0.26*	*0.26*	*0.25*
Industrial Processes and Product Use	**0.09**	**0.10**	**0.57**	**0.60**	**0.62**
Agriculture	**0.05**	**0.06**	**0.02**	**0.03**	**0.02**
Waste	**0.28**	**0.28**	**0.12**	**0.12**	**0.11**
Solid Waste Disposal	*0.18*	*0.18*	*0.02*	*0.02*	*0.00*
Wastewater Treatment and Discharge	*0.10*	*0.10*	*0.11*	*0.11*	*0.11*
TOTAL GROSS EMISSIONS	**12.32**	**12.37**	**10.55**	**10.55**	**10.35**
Natural and Working Lands	*-0.85*	*-0.61*	*-0.73*	*-0.73*	*-0.75*
TOTAL NET EMISSIONS	**11.47**	**11.76**	**9.82**	**9.82**	**9.60**

** Emissions converted to $MMTCO_2e$ with the metric GWP_{100} from the Fifth Assessment Report (AR5) of the Intergovernmental Panel on Climate Change (IPCC), also available at ipcc.ch/report/ar5/syr/. "Previous" denotes values from the 2021 Rhode Island Greenhouse Gas Inventory. For the complete 1990-2022 dataset, visit dem.ri.gov/ghg-inventory.*

TRANSPORTATION SECTOR IMPROVEMENTS

Non-Road Sources Fuel Consumption Data

In 2022, non-road sources (construction and utility equipment, watercraft, and rail) accounted for just 3% of economy-wide emissions. The *2022 Rhode Island Climate Update* identified mode-shift as an effective strategy to curb transportation emissions by reducing vehicle miles traveled (VMT) with increased ridership on buses, ferries, and trains.[17] Due to interest in this strategy, DEM sought to improve the inventory's non-road sources emissions estimates and researched the default fuel consumption data provided by EPA that has previously been used to calculate emissions. State-level fuel consumption data for EPA's State Inventory Tool (SIT) is obtained from the U.S. Department of Energy, Energy Information Administration (EIA) and the U.S. Department of Transportation, Federal Highway Administration (FHWA).[4,5] Upon closer examination, DEM found these datasets contained an unidentifiable "miscellaneous" category along with numerous inconsistencies across the timeseries.

CORRECTIONS AND IMPROVEMENTS

- Closed gaps in watercraft emissions (2001-2005, 2015, 2020) with linear interpolation of residual fuel oil estimates provided by EIA.
- Closed gaps in rail emissions (2000, 2002-2005, 2015) with linear interpolation of "distillate fuel oil sales to railroads" estimates provided by EIA upon request.
- Included gasoline lawn and garden equipment emissions for the first time with data from FHWA's *Highway Statistics Series*. Since only 2014-2022 data was available, a linear decay rate of the 2014-2022 average was applied to 1990-2013 to estimate historical emissions.
- Included gasoline recreational vehicles (ATVs, snowmobiles, etc.) emissions for the first time with data from FHWA's *Highway Statistics Series*. Since only 2014-2022 data was available, a linear decay rate of the 2014-2022 average was applied to 1990-2013 to estimate historical emissions.
- Discontinued "miscellaneous" gasoline consumption emissions from FHWA's *Highway Statistics Series*. EPA does not provide guidance on the purpose of miscellaneous gasoline consumption in SIT.

Rail emissions were historically estimated with EIA's *Fuel Oil and Kerosene Sales Report*, but EIA suspended this report after February 14, 2022. DEM requested state-level "distillate fuel oil sales data to railroads" from EIA to estimate rail emissions for 2022 as a temporary fix. Since fuel sales and fuel consumption often differ, DEM plans to obtain higher resolution distillate fuel consumption data for freight and passenger rail in Rhode Island directly from the railroads. Finally, DEM continues to use SIT to calculate all non-road source emissions since the tool contains many emissions factors that mirror EPA's *Inventory of U.S. Greenhouse Gas Emissions and Sinks*. The new fuel consumption estimates adjusted non-road source emissions between -0.02 $MMTCO_2e$ and -0.04 $MMTCO_2e$ between 1990 and 2022.

RIDEM Photo

Breene Hollow Farm in West Greenwich

AGRICULTURE SECTOR IMPROVEMENTS

The agriculture sector of the *Rhode Island Greenhouse Gas Inventory* has historically estimated emissions with generalized, and occasionally nationally disaggregated, data from SIT. This sector contains two components: livestock and soil management. DEM recently improved the data used to estimate enteric fermentation and manure management emissions from livestock and included CO_2 emissions from lime applied to agricultural soils for the first time. These methodology improvements were implemented for the entire timeseries of the *Rhode Island Greenhouse Gas Inventory*.

Livestock Emissions

DEM has historically relied on EPA's SIT to estimate livestock emissions. For both enteric fermentation and manure management, SIT provides emissions factors from EPA's *Inventory of U.S. Greenhouse Gas Emissions and Sinks* or the *2006 IPCC Guidelines for National Greenhouse Gas Inventories*. SIT also provides default livestock population data from the U.S. Department of Agriculture's (USDA) annual surveys. EPA advises users of SIT to exercise caution with default livestock data, as USDA's annual surveys do not always represent individual states. For example, USDA does not have survey data for poultry, sheep, goats, or horses in Rhode Island for any year between 1990 and 2024. Estimates for these animals are combined into an "Other States" category, which SIT evenly apportions amongst states without annual survey data. Resultingly, livestock counts are either too high or low depending on the species according to the Rhode Island State Veterinarian.

The *U.S. Census of Agriculture*, also published by USDA, is a complete tally of farms that sell more than $1,000 in agricultural commodities and is more robust than USDA's survey data. DEM chose to leverage the *U.S. Census of Agriculture* to gain state-specific livestock population counts for dairy cows, beef cows, laying hens, pullets, roosters, broiler chickens, turkeys, sheep, goats, and horses (including mules, burros, and donkeys). SIT is still used to estimate emissions, as the tool contains emissions factors that remain accurate. Since data for the *U.S. Census of Agriculture* is only collected on years ending with two or seven (i.e., 2012 and 2017), linear interpolation is necessary to "fill in the gaps" between census years. USDA's survey data is still used for bulls, calves, dairy heifers, beef heifers, breeding swine, and market swine since the *U.S. Census of Agriculture* does not detail these animals. Enteric fermentation and manure management emissions were recalculated with the improved livestock population dataset between 1990 and 2022. Emissions increased no greater than 0.01 $MMTCO_2e$ each year.

Linear interpolation is a mathematical equation that uses a step formula to connect two data points. For example, this equation assumes the state is linearly gaining – or losing – livestock between census years.

Soil Management Emissions

RIDEM Photo

Hmong farmer at JL Curran Management Area in Cranston

CO_2 emissions from lime applied to agricultural soils have never been estimated for Rhode Island since production estimates are not provided by SIT' agriculture module. EPA sources limestone production data for SIT from the U.S. Department of the Interior's U.S. Geological Survey (USGS) annual *Mineral Yearbook*. SIT does not provide data for Rhode Island because all limestone production data was marked as withheld "(W)" at the time of collection. However, DEM has always included CO_2 emissions from limestone in the industrial processes and product use (IPPU) sector because SIT's industrial processes module provides default production data. It is unclear how EPA obtained these estimates when all the Rhode Island limestone data was withheld by USGS. According to the *2006 IPCC Guidelines for National Greenhouse Gas Inventories*, CO_2 should only be counted in the IPPU sector when limestone is heated to a high temperature in a kiln. DEM researched historical limestone production in Rhode Island and found that Conklin Limestone in Lincoln produced the bicarbonate as an agricultural aggregate until 2006. This aligns with the 2006 USGS *Mineral Yearbook*, which was the final year production data was marked as withheld. Since Conklin Limestone's products were mainly used for agriculture, DEM assumed limestone production in Rhode Island was exclusively used for agricultural purposes. This mirrors the practice of SIT, which counts the CO_2 emissions from lime applied to agricultural soils only in the state that quarried the material.

To estimate the withheld limestone production data reported by USGS, the relative percentages of Rhode Island's granite and traprock production were calculated for years which data was available (2005-2006, 2011-2021). These percentages were then multiplied by Rhode Island's total crushed stone production to obtain the quantities of granite and traprock produced between 1990 and 2006. Next, these production estimates were summed and subtracted from the total amount of crushed stone produced for each year. Since USGS only reported granite, traprock, and limestone produced in Rhode Island, the remaining amount of crushed stone after the granite and traprock were removed was assumed to be limestone. SIT was used to calculate the CO_2 emissions from lime applied to agricultural soils with an IPCC emissions factor. The addition of this component added between 0.01 $MMTCO_2e$ and 0.03 $MMTCO_2e$ to the agriculture sector each year between 1990 and 2006.

NATURAL AND WORKING LANDS SECTOR IMPROVEMENTS

Inclusion of Flooded Land Emissions

Credit: New England Water Science Center

The eastern side of the Scituate Reservoir, facing northwest.

Many categories of the natural and working lands (NWL) sector continue to mirror EPA's *Inventory of U.S. Greenhouse Gas Emissions and Sinks by State* (the national inventory report – "NIR" by state). In August 2024, EPA published the 1990-2022 NIR by state with an improved database. The CO_2 and CH_4 flux from flooded land remaining flooded land and land converted to flooded land – both categories of wetlands – were previously omitted because the metadata was not accessible. Flooded lands are waterbodies that exist from human activities.[16] In Rhode Island, reservoirs and dammed ponds are the most prominent flooded lands. Large canals and drainage ditches are also considered flooded lands in other parts of the U.S. Seasonally flooded wetlands, such as riparian floodplains, are not considered flooded land

by the IPCC. Flooded land emits CO_2 from the decomposition of soil organic matter within the waterbody and CH_4 from anoxic water conditions (areas depleted of dissolved oxygen). Since the land area which contains the reservoir or dammed pond was not originally flooded, these emissions are considered anthropogenic.

Flooded land emissions were calculated with surface area data from the National Hydrography dataset, the National Inventory of Dams, the National Wetlands Inventory, the Navigable Waterways Network, and EPA's Safe Drinking Water Information System.[18] Reservoirs are considered surface water bodies larger than 19.77 acres (8 hectares) that have been flooded for more than 20 years. Since Rhode Island is located along the coastal plain of New England, a "warm temperate moist" emission factor based on the state's climate was used to calculate emissions. The vast majority of Rhode Island's CH_4 emissions from flooded land originate from reservoirs (0.04 $MMTCO_2e$/year) and dammed freshwater ponds (0.01 $MMTCO_2e$/year). Only very small quantities of CO_2 (<0.01 $MMTCO_2e$) were emitted from flooded lands each year. Inclusion of this category results in an additional 0.05 $MMTCO_2e$ of methane emissions. Overall, Rhode Island's wetlands included in this assessment are responsible for 0.04 $MMTCO_2e$ of GHG emissions since 0.01 $MMTCO_2e$ are removed by coastal wetlands each year. Emissions from natural lakes, ponds, and inland wetlands are not currently estimated because the IPCC does not recommend inclusion of these waterbodies in national inventories.

Inclusion of Forest Land Carbon Storage

RIDEM Photo
Killingly Pond Management Area, Glocester

The net emissions flux from forest land previously included the CO_2 removed by aboveground biomass and the CH_4 and N_2O emissions from forest fires.[19] According to IPCC guidelines, the forest land remaining forest land category has more components than just aboveground biomass. Belowground biomass (roots), deadwood, litter (duff, humus, or fine woody debris), mineral soil, and organic soil also have a net carbon flux. These components were previously omitted because the metadata in EPA's NIR by state was not accessible. The software to view this dataset was significantly improved in August 2024, which allowed DEM to research the belowground biomass, deadwood, leaf litter, mineral soil, and organic soil estimates. Subsequent review of the methodologies used by EPA to calculate the net CO_2 flux from these components verified the level of uncertainty to be acceptable for the *Rhode Island Greenhouse Gas Inventory*.

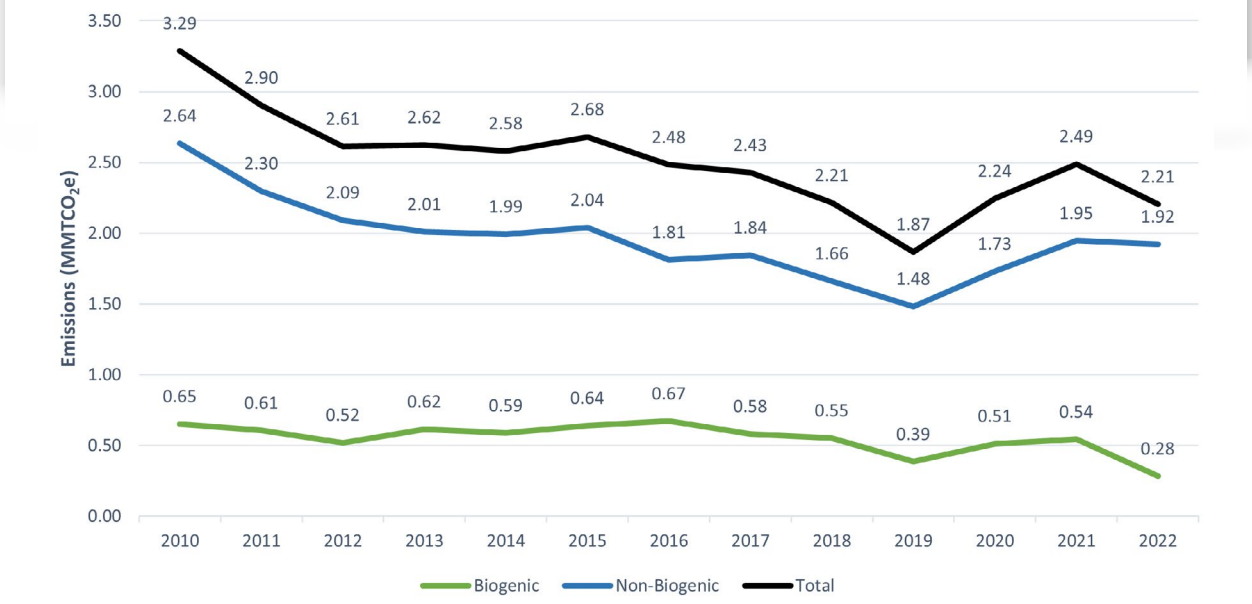
Carbon constantly flows through a forest between different storage pools or "stocks". For example, carbon stored in a tree remains after it dies if the tree is not combusted in a forest fire or harvested as a wood product. Instead of "aboveground biomass", the tree is now "non-stocked" or "deadwood". The tree's carbon will eventually transfer to the soil via decomposition, and over millions of years, back to deep underground deposits. Previous iterations of the *Rhode Island Greenhouse Gas Inventory* only included the CO_2 removed from the atmosphere by aboveground biomass. No regard was given to the carbon transferred between any of the other storage pools. The carbon storage pools of belowground biomass (-0.04 $MMTCO_2e$), deadwood (-0.28 $MMTCO_2e$), litter (0.01 $MMTCO_2e$), mineral soil (0.04 $MMTCO_2e$), and organic soil (0.01 $MMTCO_2e$) are now included in the NWL sector for the entire timeseries.

Tree mortality in Rhode Island from diseases and pests have increased since 1990. Resultingly, the CO_2 stored in deadwood increased by 367% from 1990 to 2022. The overall NWL sector grew by 22.5% in the last 32 years because of carbon transferred from the aboveground biomass storage pool to the deadwood storage pool. While Rhode Island's ability to naturally remove carbon from the atmosphere has decreased by 6% since 1990 because of less forested acres, **the amount of carbon stored in forests has increased.** Thus, the NWL sector offset a greater percentage of Rhode Island's gross emissions in 2022 (7.2%) than in 1990 (4.9%). This trend is consistent with EPA's NIR by state. Harvested wood products for heating (i.e., woodstoves) or construction are currently not estimated and require further study.

CARBON DIOXIDE EMISSIONS FROM BIOGENICALLY-SOURCED ELECTRICITY

As required by the *Rhode Island 2022 Climate Update* and in alignment with Federal greenhouse gas reporting conventions, CO_2 from the combustion or decay of biogenic material is treated as CO_2e-neutral for purposes of compliance with the Act on Climate. According to the *2006 IPCC Guidelines for National Greenhouse Gas Inventories*, CO_2 emissions from short-lived biogenic material (i.e., biogas, biomass, digester gas, and landfill gas) is balanced by carbon uptake prior to harvest, within the uncertainties of the estimates, so the net CO_2 emission is zero.[16] For long-lived biogenic material (i.e. wood), it is assumed the jurisdiction which combusts the product deducts the CO_2 sequestration potential from their state's greenhouse gas inventory. Although wood is not combusted for electricity in Rhode Island, the feedstock is combusted to heat residential and commercial buildings. DEM will work to account for the impact of harvested wood products in future iterations of the *Rhode Island Greenhouse Gas Inventory*. Biogenic emissions from electricity consumption are reported for informational purposes only. Biogenic fuel types include biogas, biomass, digester gas, landfill gas, and wood. Non-biogenic fuel types include coal, kerosene, petroleum, natural gas, and trash-to-energy. In 2022, CO_2 emissions from electricity produced from biogas, biomass, and landfill gas were 0.28 $MMTCO_2e$.

2020-2022 ELECTRICITY CONSUMPTION EMISSIONS



End Notes

1. 2021 Act on Climate, R.I. Gen. Laws § 42-6.2-9 (2021). http://webserver.rilin.state.ri.us/Statutes/TITLE42/42-6.2/42-6.2-9.htm
2. Bureau of Transportation Statistics. (2022). *T-100 Market data*. [Data set]. U.S. Department of Transportation. https://www.transtats.bts.gov/Data_Elements.aspx?Data=1
3. The Permanent Air Quality Monitoring Act, R.I. Gen. Laws § 1-7-6 (2007). http://webserver.rilin.state.ri.us/Statutes/TITLE1/1-7/1-7-6.HTM
4. U.S. Energy Information Administration. (2024). *State Energy Data System: 1960-2022 (complete)*. [Data set]. U.S. Department of Energy. https://www.eia.gov/state/seds/
5. U.S. Federal Highway Administration. (2024). *Highway Statistics Series*. [Data set]. U.S. Department of Transportation. https://www.fhwa.dot.gov/policyinformation/statistics.cfm
6. Carbon dioxide (CO_2) from the combustion of organic energy resources is considered biogenic in origin and is treated as CO_2e-neutral for purposes of compliance with the Act on Climate. Methane (CH_4) and nitrous oxide (N_2O) emissions from biogenic material are always included in sector totals.
7. Degree days are the difference between the daily mean temperature and 65°F. If the daily mean temperature is below 65°F, then heating degree days (HDDs) are calculated. Conversely, if the daily mean temperature is above 65°F, then cooling degree days (CDDs) are calculated. Years with greater amounts of HDDs correlate with higher residential, and to some extent commercial, building emissions.
8. NOAA National Centers for Environmental Information, Federal Aviation Administration. (2024). *5-Minute Surface Weather Observations from the Automated Surface Observing Systems (ASOS)* Network. [Data set]. U.S. Department of Commerce and U.S. Department of Transportation. http://climod2.nrcc.cornell.edu/
9. Rhode Island Office of Energy Resources. (2024). *Clean Heat Rhode Island Rebate Statistics*. [Data set]. State of Rhode Island, Department of Administration. https://energy.ri.gov/heating-cooling/clean-heat-ri/clean-heat-rhode-island-statistics
10. Electricity consumption is the only sector that includes emissions from outside of Rhode Island's geographic borders. This deviation from international reporting guidelines was unanimously endorsed by the EC4 on May 11, 2016.
11. Renewable electricity sources include biogas, biomass, hydroelectric/hydropower, landfill gas, nuclear, solar photovoltaic, and wind.
12. Renewable Energy Standard, R.I. Gen. Laws § 39-26-4 (2004). http://webserver.rilin.state.ri.us/Statutes/TITLE39/39-26/39-26-4.htm.
13. ISO New England Newswire. (April 28, 2022). *Winter 2021/2022 recap: Fuel prices drove high energy costs in New England; grid operated reliably amid mild weather*. ISO New England. https://isonewswire.com/2022/04/28/winter-2021-2022-recap-fuel-prices-drove-high-energy-costs-in-new-england-grid-operated-reliably-amid-mild-weather/
14. Public Utilities Commission Docket No. 5099 – The Narragansett Electric Co. d/b/a National Grid. Gas Infrastructure, Safety, and Reliability (ISR) Plan for FY 2022 (filed 12/18/2020). https://ripuc.ri.gov/eventsactions/docket/5099page.html
15. Rhode Island's Low and Zero Emission Vehicle Program. 250-RICR-120-05-37. https://rules.sos.ri.gov/regulations/part/250-120-05-37
16. Intergovernmental Panel on Climate Change. (2006). *2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Prepared by the National Greenhouse Gas Inventories Programme, Eggleston H.S., Buendia L., Miwa K., Ngara T. and Tanabe K. (eds). Published: IGES, Japan. https://www.ipcc-nggip.iges.or.jp/public/2006gl/index.html
17. Rhode Island Executive Climate Change Coordinating Council. (2022). *Rhode Island 2022 Climate Update*. https://climatechange.ri.gov/act-climate/2025-climate-update
18. U.S. Environmental Protection Agency. (2024). *Inventory of U.S. Greenhouse Gas Emissions and Sinks by State*. U.S. Environmental Protection Agency, Office of Atmospheric Protection. https://www.epa.gov/ghgemissions/state-ghg-emissions-and-removals
19. Rhode Island Department of Environmental Management. (2022). *Accounting Carbon Sequestration from Land Use, Land Use Change, and Forestry*. State of Rhode Island, Department of Environmental Management. https://dem.ri.gov/sites/g/files/xkgbur861/files/2022-10/Comments%20Combined.pdf

RECOMMENDED CITATION (APA):

Rhode Island Department of Environmental Management. (2024). ***2022 Rhode Island Greenhouse Gas Inventory***. State of Rhode Island, Department of Environmental Management. https://dem.ri.gov/ghg-inventory.